

What is claimed is:

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1 1. In a communication network comprising an ingress node, a
2 plurality of core nodes connected by links to the ingress node, and an egress
3 node connected by links to the ingress node via the core nodes, said ingress
4 node receiving communication traffic of the network and said egress node
5 delivering communication traffic of the network, an apparatus for designing a
6 plurality of communication paths between said ingress node and said egress
7 node, the apparatus comprising:
8 means for defining an objective function for minimizing a number of
9 candidate tree graphs for accommodating said communication paths;
10 means for defining a first constraint equation for causing all of said
11 candidate tree graphs to form a tree;
12 means for defining a second constraint equation for accommodating said
13 communication paths in one of said candidate tree graphs;
14 means for defining a third constraint equation for determining whether
15 each of said candidate tree graphs is used to accommodate said communication
16 paths; and
17 means for solving a mathematical programming problem formed by said
18 objective function, and said first, second and third constrain equations to
19 obtain a plurality of trees in which said communication paths can be
20 accommodated.

1 2. In a communication network comprising an ingress node, a
2 plurality of core nodes connected by links to the ingress node, and an egress

3 node connected by links to the ingress node via the core nodes, said ingress
4 node receiving communication traffic of the network and said egress node
5 delivering communication traffic of the network, an apparatus for designing a
6 plurality of communication paths between said ingress node and said egress
7 node, the apparatus comprising:

8 means for storing an existing tree and determining whether said
9 communication paths can be accommodated in said existing tree;

10 means for defining an objective function for minimizing a number of
11 candidate tree graphs for accommodating ones of said communication paths
12 which cannot be accommodated in said existing tree;

13 means for defining a first constraint equation for causing all of said
14 candidate tree graphs to form a tree if all of said communication paths cannot
15 be accommodated in said existing tree;

16 means for defining a second constraint equation for accommodating said
17 ones of communication paths in one of said candidate tree graphs;

18 means for defining a third constraint equation for determining whether
19 each of said candidate tree graphs is used to accommodate at least one of said
20 communication paths; and

21 means for solving a mathematical programming problem formed by said
22 objective function, and said first, second and third constrain equations to
23 obtain a plurality of trees in which said ones of communication paths can be
24 accommodated.

1 ~~3.~~ In a communication network comprising an ingress node, a
2 plurality of core nodes connected by links to the ingress node, and an egress

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3 node connected by links to the ingress node via the core nodes, said ingress
4 node receiving communication traffic of the network and said egress node
5 delivering communication traffic of the network, an apparatus for designing a
6 plurality of communication paths between said ingress node and said egress
7 node, the apparatus comprising:
8 means for defining a first constraint equation for causing all candidate
9 tree graphs to form a tree;
10 means for defining a second constraint equation for accommodating said
11 communication paths in one of said candidate tree graphs;
12 means for embedding non-negative artificial variables into said first and
13 second constraint equations;
14 means for defining an objective function for minimizing a total number
15 of said non-negative artificial variables; and
16 means for solving a mathematical programming problem formed by said
17 objective function, and said first and second constrain equations to obtain a
18 plurality of trees in which said communication paths can be accommodated.

1 ~~4~~ In a communication network comprising an ingress node, a
2 plurality of core nodes connected by links to the ingress node, and an egress
3 node connected by links to the ingress node via the core nodes, said ingress
4 node receiving communication traffic of the network and said egress node
5 delivering communication traffic of the network, an apparatus for designing a
6 plurality of communication paths between said ingress node and said egress
7 node, the apparatus comprising:
8 means for storing an existing tree and determining whether said

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9 communication paths can be accommodated in said existing tree;
10 means for defining a first constraint equation for accommodating ones
11 of said communication paths which cannot be accommodated in said existing
12 tree in one of said candidate tree graphs;

13 means for defining a second constraint equation for causing all of said
14 candidate tree graphs to form a tree;

15 means for embedding non-negative artificial variables into said first and
16 second constraint equations;

17 means for defining an objective function for minimizing a total number
18 of said non-negative artificial variables; and

19 means for solving a mathematical programming problem formed by
20 said objective function, and said first and second constrain equations to
21 obtain a plurality of trees in which said ones of communication paths can be
22 accommodated.

1 ~~5.~~ In a communication network comprising an ingress node, a
2 plurality of core nodes connected by links to the ingress node, and an egress
3 node connected by links to the ingress node via the core nodes, said ingress
4 node receiving communication traffic of the network and said egress node
5 delivering communication traffic of the network, a method of designing a
6 plurality of communication paths between said ingress node and said egress
7 node, the method comprising:

8 defining an objective function for minimizing a number of candidate tree
9 graphs for accommodating said communication paths;

10 defining a first constraint equation for causing all of said candidate tree

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11 graphs to form a tree;
12 defining a second constraint equation for accommodating said
13 communication paths in one of said candidate tree graphs;
14 defining a third constraint equation for determining whether each of
15 said candidate tree graphs is used to accommodate said communication paths;
16 and
17 solving a mathematical programming problem formed by said objective
18 function, and said first, second and third constrain equations to obtain a
19 plurality of trees in which said communication paths can be accommodated.

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6. In a communication network comprising an ingress node, a
2 plurality of core nodes connected by links to the ingress node, and an egress
3 node connected by links to the ingress node via the core nodes, said ingress
4 node receiving communication traffic of the network and said egress node
5 delivering communication traffic of the network, a method of designing a
6 plurality of communication paths between said ingress node and said egress
7 node, the method comprising:
8 storing an existing tree and determining whether said communication
9 paths can be accommodated in said existing tree;
10 defining an objective function for minimizing a number of candidate tree
11 graphs for accommodating ones of said communication paths which cannot be
12 accommodated in said existing tree;
13 defining a first constraint equation for causing all of said candidate tree
14 graphs to form a tree if all of said communication paths cannot be
15 accommodated in said existing tree;

16 defining a second constraint equation for accommodating said ones of
17 communication paths in one of said candidate tree graphs;

18 defining a third constraint equation for determining whether each of
19 said candidate tree graphs is used to accommodate at least one of said
20 communication paths; and

21 solving a mathematical programming problem formed by said objective
22 function, and said first, second and third constrain equations to obtain a
23 plurality of trees in which said ones of said communication paths can be
24 accommodated.

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1 ~~X~~ In a communication network comprising an ingress node, a
2 plurality of core nodes connected by links to the ingress node, and an egress
3 node connected by links to the ingress node via the core nodes, said ingress
4 node receiving communication traffic of the network and said egress node
5 delivering communication traffic of the network, a method of designing a
6 plurality of communication paths between said ingress node and said egress
7 node, the method comprising:

8 defining a first constraint equation for causing all candidate tree graphs
9 to form a tree;

10 defining a second constraint equation for accommodating said
11 communication paths in one of said candidate tree graphs;

12 embedding non-negative artificial variables into said first and second
13 constraint equations;

14 defining an objective function for minimizing a total number of said
15 non-negative artificial variables; and

16 solving a mathematical programming problem formed by said objective
17 function, and said first and second constrain equations to obtain a plurality of
18 trees in which said communication paths can be accommodated.

1 ~~8.~~ In a communication network comprising an ingress node, a
2 plurality of core nodes connected by links to the ingress node, and an egress
3 node connected by links to the ingress node via the core nodes, said ingress
4 node receiving communication traffic of the network and said egress node
5 delivering communication traffic of the network, a method of designing a
6 plurality of communication paths between said ingress node and said egress
7 node, the method comprising:

8 storing an existing tree and determining whether said communication
9 paths can be accommodated in said existing tree;

10 defining a first constraint equation for accommodating ones of said
11 communication paths which cannot be accommodated in said existing tree in
12 one of said candidate tree graphs;

13 defining a second constraint equation for causing all of said candidate
14 tree graphs to form a tree;

15 embedding non-negative artificial variables into said first and second
16 constraint equations;

17 defining an objective function for minimizing a total number of said
18 non-negative artificial variables; and

19 solving a mathematical programming problem formed by said objective
20 function, and said first and second constrain equations to obtain a plurality of
21 trees in which said ones of communication paths can be accommodated.

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1 9. In a communication network comprising an ingress node, a
2 plurality of core nodes connected by links to the ingress node, and an egress
3 node connected by links to the ingress node via the core nodes, said ingress
4 node receiving communication traffic of the network and said egress node
5 delivering communication traffic of the network, a storage medium for storing
6 an algorithm for operating a computer to design a plurality of communication
7 paths between said ingress node and said egress node, said algorithm
8 comprising:
9 defining an objective function for minimizing a number of candidate tree
10 graphs for accommodating said communication paths;
11 defining a first constraint equation for causing all of said candidate tree
12 graphs to form a tree;
13 defining a second constraint equation for accommodating said
14 communication paths in one of said candidate tree graphs;
15 defining a third constraint equation for determining whether each of
16 said candidate tree graphs is used to accommodate said communication paths;
17 and
18 solving a mathematical programming problem formed by said objective
19 function, and said first, second and third constrain equations to obtain a
20 plurality of trees in which said communication paths can be accommodated.

1 10. In a communication network comprising an ingress node, a
2 plurality of core nodes connected by links to the ingress node, and an egress
3 node connected by links to the ingress node via the core nodes, said ingress
4 node receiving communication traffic of the network and said egress node

5 delivering communication traffic of the network, a storage medium for storing
6 an algorithm for operating a computer to design a plurality of communication
7 paths between said ingress node and said egress node, said algorithm
8 comprising:

9 storing an existing tree and determining whether said communication
10 paths can be accommodated in said existing tree;

11 defining an objective function for minimizing a number of candidate tree
12 graphs for accommodating ones of said communication paths which cannot be
13 accommodated in said existing tree;

14 defining a first constraint equation for causing all of said candidate tree
15 graphs to form a tree if all of said communication paths cannot be
16 accommodated in said existing tree;

17 defining a second constraint equation for accommodating said ones of
18 communication paths in one of said candidate tree graphs;

19 defining a third constraint equation for determining whether each of
20 said candidate tree graphs is used to accommodate at least one of said
21 communication paths; and

22 solving a mathematical programming problem formed by said objective
23 function, and said first, second and third constrain equations to obtain a
24 plurality of trees in which said communication paths can be accommodated.

1 ~~11~~ In a communication network comprising an ingress node, a
2 plurality of core nodes connected by links to the ingress node, and an egress
3 node connected by links to the ingress node via the core nodes, said ingress
4 node receiving communication traffic of the network and said egress node

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5 delivering communication traffic of the network, a storage medium for storing
6 an algorithm for operating a computer to design a plurality of communication
7 paths between said ingress node and said egress node, said algorithm
8 comprising:
9 defining a first constraint equation for causing all candidate tree graphs
10 to form a tree;
11 defining a second constraint equation for accommodating said
12 communication paths in one of said candidate tree graphs;
13 embedding non-negative artificial variables into said first and second
14 constraint equations;
15 defining an objective function for minimizing a total number of said
16 non-negative artificial variables; and
17 solving a mathematical programming problem formed by said objective
18 function, and said first and second constrain equations to obtain a plurality of
19 trees in which said ones of said communication paths can be accommodated.

1 ~~12.~~ In a communication network comprising an ingress node, a
2 plurality of core nodes connected by links to the ingress node, and an egress
3 node connected by links to the ingress node via the core nodes, said ingress
4 node receiving communication traffic of the network and said egress node
5 delivering communication traffic of the network, a storage medium for storing
6 an algorithm for operating a computer to design a plurality of communication
7 paths between said ingress node and said egress node, said algorithm
8 comprising:
9 storing an existing tree and determining whether said communication

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10 paths can be accommodated in said existing tree;
11 defining a first constraint equation for accommodating ones of said
12 communication paths which cannot be accommodated in said existing tree in
13 one of said candidate tree graphs;
14 defining a second constraint equation for causing all of said candidate
15 tree graphs to form a tree;
16 embedding non-negative artificial variables into said first and second
17 constraint equations;
18 defining an objective function for minimizing a total number of said
19 non-negative artificial variables; and
20 solving a mathematical programming problem formed by said objective
21 function, and said first and second constrain equations to obtain a plurality of
22 trees in which said ones of communication paths can be accommodated.

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